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# Ridge Tillage for Managing Irrigation Water on the U.S. Southern Great Plains*

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ABSTRACT

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Ridge tillage (furrowing) is widely used on irrigated land on the Southern Great Plains, especially on soils adapted to gravity flow, furrow irrigation. Ridge tillage is also used in conjunction with surge irrigation, limited irrigation, and precision water application techniques. This report reviews the effects of ridge tillage on irrigation water management and crop establishment. Furrow irrigation, made possible by ridge tillage, results in relatively uniform distribution of water in the field with length of run. Exceptions are on slowly permeable soils where water infiltration at the lower end of the field may be low, and on moderately permeable soils where infiltration and losses to deep percolation may be high. Practices that result in more uniform water application on slowly permeable soils include allowing tailwater runoff, surge irrigation, deep loosening of the soil (especially at the lower end of the field), and precision water application. On moderately permeable soils, furrow compaction, surge irrigation, and precision water application practices help to reduce water losses resulting from high infiltration rates and deep percolation. The effects of these practices on water infiltration and irrigation efficiency are discussed. Also discussed are the advantages and disadvantages of ridge tillage for crop establishment.

## INTRODUCTION

About 66% of the total irrigated land in Texas is in the 41-county area that totally or partially overlies the Texas High Plains' portion of the Ogallala Aquifer (Fig. 1) (Musick et al., 1988a,b). Irrigation in the Texas High Plains reached a peak of 2.43 Mha in 1974. By 1984, the irrigated area had declined to 1.82 Mha, and further declines have occurred since then. The declines are attributed to continuing groundwater depletion of the Ogallala Aquifer, increasing pumping energy costs, low farm profits in recent years, and government set-aside programs (Musick et al., 1988a).

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*Contribution from USDA, Agricultural Research Service, P.O. Drawer 10, Bushland, TX 79012.

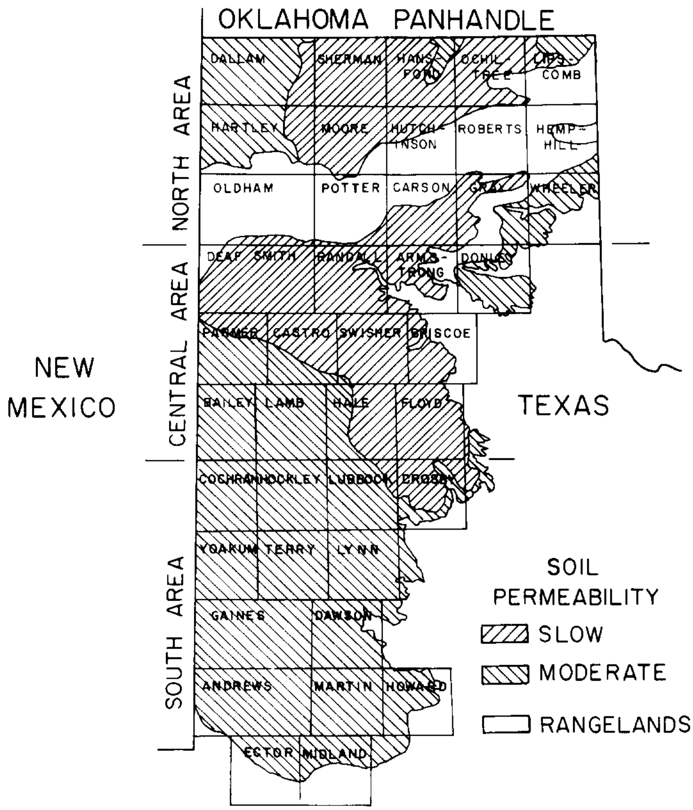


Fig. 1. The irrigated area of the Texas High Plains overlying the Ogallala aquifer divided into the North 15-, Central 12-, and South 14-county areas and into the major soil groups of slow and moderate permeability (from Musick et al., 1988b).

In 1986, about 40% of the cropland in the Texas High Plains was irrigated, the primary irrigated crops being cotton (*Gossypium hirsutum* L. – 0.387 Mha), grain sorghum (*Sorghum bicolor* (L.) Moench – 0.226 Mha), winter wheat (*Triticum aestivum* L. – 0.334 Mha), and corn (*Zea mays* L. – 0.185 Mha). Winter wheat and grain sorghum were the dominant crops in the northern area, wheat, sorghum, and cotton in the central area, and cotton and sorghum in the southern area (see Fig. 1 for areas). Corn was grown mostly in the central and northern areas (Musick et al., 1988a).

In 1984, about 63% of the total irrigated area was furrow-irrigated (ridge tilled), and the percentage has decreased since then (actual percentage unknown). Almost all of the remaining area is sprinkler-irrigated. The decrease in furrow irrigation has resulted from the overall decrease in total irrigated area and an increase in sprinkler irrigation in the region. Sprinkler irrigation generally results in higher water use efficiency than furrow irrigation. Although furrow irrigation is used for around 60% of the entire Texas High Plains region, it is used on around 90% of the slowly permeable clay soils. Sprinkler irrigation predominates on more permeable soils (Fig. 1). Furrow and sprinkler irrigation methods also are used for similar conditions in other portions of the Southern Great Plains (New Mexico and Oklahoma) as well as in the Central Great Plains (Colorado, Kansas, and Nebraska).

This report is devoted to the effects of ridge tillage, which permits furrow irrigation, on irrigation water management and on crop establishment, growth, and yield.

## IRRIGATION WATER MANAGEMENT

Ridge tillage (furrowing) plays a major role in irrigation water management in the Texas High Plains, especially on soils suitable for gravity flow, furrow irrigation. Ridge tillage is important also for surge irrigation, limited irrigation techniques, and precision water application techniques.

### *Gravity flow irrigation*

Gravity flow irrigation is the predominant method of irrigation on the slowly permeable soils of the Texas High Plains (Figs. 2 and 3). Pullman clay loam (fine, mixed, thermic Torrertic Paleustoll) and Sherm silty clay loam (fine,

Fig. 2. Applying a pre-plant furrow irrigation through gated pipe to Pullman clay loam at Bushland, Texas.

Fig. 3. Furrow irrigating grain sorghum through siphon tubes on Pullman clay loam near Tulia, Texas (USDA Soil Conservation Service photo).

mixed, mesic Torrertic Paleustoll) are the major slowly permeable soils. These soils are non-typical with respect to intake family, but are generally given values of 2.5–5.0 mm $h^{-1}$. The Pullman soils cover about 1.53 Mha (total area) while the Sherm soils cover about 0.52 Mha (total area), including a small portion in Oklahoma (Unger and Pringle, 1981, 1986).

The Pullman and Sherm soils are well adapted to furrow irrigation because of their relatively flat topography (much of it has a slope of less than 1.0%). The flat topography permits use of low-furrow grades (mostly 0.1–0.5%), which, along with the low permeability, allows irrigation of furrows 800 m long (sometimes up to 1600 m), usually without major water losses due to deep percolation. Such long furrows and low permeability permit long irrigation sets (time that water is applied to a given set of furrows), thus minimizing the labor needed to irrigate a unit of land area. Because of the flat topography, the land can be prepared for irrigation without major land forming in many cases. The furrowing operation alone is often adequate to provide for water flow by gravity. In other cases, land planing (smoothing) is performed to remove minor surface irregularities, thus improving water flow and distribution in the field. The ridges and furrows may be permanent, but are usually destroyed and re-established by tillage each year.

Field length, furrow grade, soil permeability, water availability, and soil water holding capacity are important factors in designing a furrow irrigation system. To minimize labor requirements, most systems are designed for irri-

Fig.4. Establishing ridges and furrows at a 1.5-m spacing on Pullman clay loam at Bushland, Texas (photo provided by R.R. Allen, USDA Agricultural Research Service).

gation sets of 24 hours on slowly permeable soils and 12 hours on moderately permeable soils.

Furrow spacing is usually 0.75 or 1.0 m, but 1.5 m spacings with two rows of cultivated crops per ridge are sometimes used (Fig. 4). Wide spaced and alternate-furrow irrigation may be practiced on the flatter slopes, especially where the supply of water for irrigation is limited. Seasonal precipitation in the semiarid climate contributes to the success of wide spaced furrow irrigation.

While low water permeability permits use of long furrows, it also contributes to decreasing soil water storage with distance down the furrows (Musick et al., 1973; Schneider et al., 1976). Limited soil water storage on a lower section of the field can result in soil water deficits, plant water stress, and lower yields unless special attempts are made to equalize water storage throughout the length of the field or irrigations are applied frequently. However, when water supplies are limited, the reduced lower-field storage is efficiently used by the drought-tolerant crops (winter wheat, grain sorghum, and cotton) commonly grown in the region.

One practice widely used to improve water distribution is to allow water to flow from the field, thus providing the infiltration-opportunity time for storing water in the profile near the lower end of the field. In practice, such runoff, called tailwater runoff, may be permitted for 6–8 h. Soil water content at different positions in a 548-m long field before and after the first furrow irrigation for grain sorghum (while the soil surface was loose) is shown in Fig. 5.

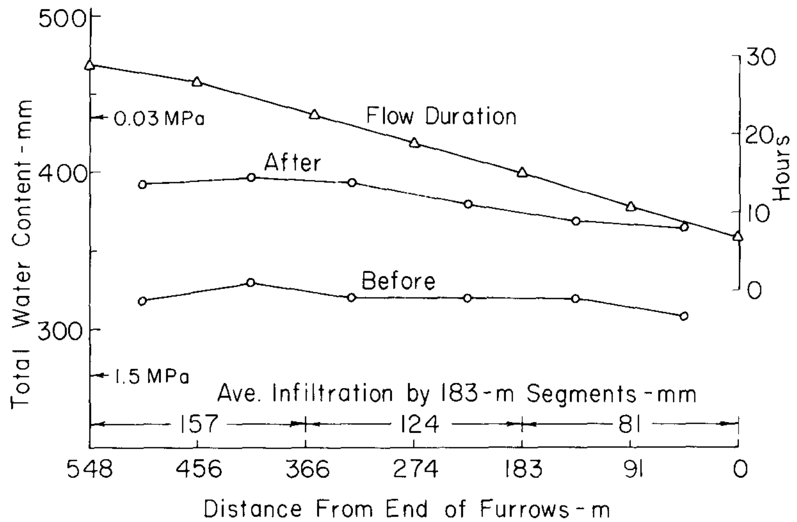


Fig. 5. Total soil water contents to the 1.2-m depth with length of run on Pullman clay loam before and after the first growing-season irrigation for grain sorghum. Flow duration, infiltration by segments, and matric potentials are also given (redrawn from Musick et al., 1973).

About seven hours of tailwater runoff occurred. Infiltration decreased as duration of flow at the different positions decreased. As a result, average infiltration at the upper 183-m long segment was 157 mm as compared with 81 mm at the lower 183-m long segment. At subsequent irrigations (also with about seven hours of tailwater runoff), when the soil had been consolidated by previous irrigations but had extensively cracked because of water extraction by the sorghum, average infiltration at the upper and lower segments was 127 and 81 mm, respectively (Musick et al., 1973) (data not shown). The more uniform distribution at the later irrigations was attributed to soil cracking which resulted in relatively rapid infiltration into the low permeability soil. With shorter times of tailwater runoff, water content at lower field positions often declines sharply on low permeability soils (Schneider et al., 1976).

Allowing tailwater runoff to occur reduces the efficiency of water storage in the crop root zone but increases the uniformity of storage. To obtain uniform field wetting requires substantial tailwater runoff time and volume, which increase water application, water losses, and cost of production unless tailwater runoff is captured for other purposes or recycled through the irrigation system. Tailwater recovery and recycling systems (designed for about 65% re-use efficiency) are widely used in the ridge–furrow irrigated area of the Texas High Plains. While such systems reduce water loss from the system, recycled water must be pumped (a second time) to the input end of the field, thus adding to the production cost.

In addition to the problem of allowing tailwater runoff to achieve relatively uniform wetting of the entire field of slowly permeable soils such as the Pullman and Sherm, other problems are the limited wetting with depth of the profile, and the non-uniform rate of water advance and infiltration resulting from wheel traffic occurring in some furrows but not in others. On the Pullman soil, limited wetting with depth was overcome by deep tillage. Musick and Dusek (1975) showed that irrigation wetted the soil into the 0.3–0.6 m layer with 0.2-m deep plowing and into the 0.6–0.9-m layer with 0.4-m deep plowing. Deeper plowing (0.6 or 0.8 m) resulted in soil wetting into the 0.9–1.2-m layer, but also resulted in percolation losses in some cases. Hence, the 0.4-m deep plowing was considered optimum. Deep plowing was considered most effective when used on the lower portion of fields that normally experienced significant yield reductions owing to limited water infiltration. Deep tillage of the lower portion of the field increases water storage and yield uniformity with distance along the furrows, especially under conditions of limited tailwater runoff.

Traffic in furrows causes soil compaction. Hence, water advances more rapidly and infiltration is lower in traffic than in non-traffic furrows when infiltration times are equal. Unless water application rates are adjusted for wheel traffic effects, excessive tailwater runoff usually occurs from the traffic furrows. A soil loosening operation before irrigation can minimize differences in water infiltration between traffic and non-traffic furrows. Another technique to improve uniformity of water infiltration is to use wide bed–furrow systems with wheel traffic kept on the beds (Allen and Musick, 1972; Allen, 1985).

On moderately permeable soils, furrow irrigation may result in excessive water infiltration and substantial losses to deep percolation. These problems can be minimized by intentionally compacting the furrows with wheel traffic (Musick et al., 1985; Musick and Pringle, 1986). When Musick and Pringle (1986) increased the density of 400 m long, 1.5 m spaced furrows on Olton clay loam (fine, mixed, thermic Aridic Paleustoll) with tractor traffic (one pass), infiltration and deep percolation were reduced by 33% and 50%, respectively, compared with values in non-traffic furrows. Corn yields were not affected by the reduced infiltration in the two year study because the furrow compaction more closely balanced the water infiltration with the soil water storage capacity at the time of irrigation.

### *Surge-flow irrigation*

With surge-flow irrigation, water is supplied intermittently to alternate sets of furrows, generally with the goal of reducing infiltration (Kemper et al., 1988). Hence, it has been adopted extensively for reducing infiltration and deep percolation losses, mostly on moderately permeable soils where furrow irrigation with gated pipes is practiced.

Kemper et al. (1988) discussed the mechanisms by which surge irrigation reduces the infiltration rates of a silty loam soil. Besides minimizing percolation losses, surge irrigation also has the potential for improving water infiltration uniformity throughout the length of the field and for decreasing tailwater runoff. A normal surge-flow irrigation practice is to use an available water supply to irrigate an area larger than would be irrigated under conventional continuous flow conditions. Irrigation of the larger area is possible because of the decreased infiltration and losses to deep percolation and tailwater runoff.

Musick et al. (1987) evaluated surge-flow irrigation throughout the growing season for corn on Olton clay loam. Use of surge-flow irrigation reduced infiltration by 32% when the surface soil was loose because of tillage and by an average of 17% for seasonal irrigations when the surface soil was consolidated by previous irrigations. These reductions were relative to conventional continuous flow furrow irrigation on the same soil. In the study, surge irrigation reduced total water infiltration during seven irrigations by 259 mm (992 mm for continuous vs. 733 mm for surge) and tailwater runoff from 189 to 82 mm, without reducing corn yields.

In comparing the effects of using surge-flow irrigation in non-traffic furrows and continuous-flow irrigation in furrows compacted by wheel traffic, Musick and Pringle (1986) and Musick et al. (1987) found that both practices reduced excessive infiltration into the Olton clay loam. However, the surge-flow system provided an added benefit of being able to provide reduced tailwater runoff.

### *Precision water application*

Although furrow irrigation (gravity flow or surge) results in moderately uniform water application throughout a field, greater uniformity has been achieved through the use of the LEPA (low energy precision application) irrigation system (Lyle and Bordovsky, 1981). The system distributes water directly to furrows at a very low pressure through drop tubes and emitters that are located 5–10 cm above the soil surface. The water is delivered to the field through a modified overhead sprinkler system. The objectives of the LEPA system are to reduce water and pumping energy requirements, and to reduce the effects of soil spatial variability on furrow irrigation and of wind and temperature on sprinkler irrigation efficiencies. By including basin tillage or furrow dikes (tied ridges), potential tailwater runoff due to high application rates per unit land area is prevented. Basin tillage also prevents storm runoff and increases utilization of rainfall for crop production. Deep chiseling (0.3–0.4 m) is also practiced for increasing infiltration rates and reducing runoff.

The results of application efficiency studies in 1980 and 1981 involving LEPA, sprinkler, and furrow irrigation systems with basin and conventional tillage are summarized in Table 1. The studies were conducted under a wide range of wind speeds (0.9–9.9 m $s^{-1}$), while the winds were generally from a southerly (SE–SW) direction. The efficiencies were acceptable for each system, but the sprinkler and furrow systems resulted in a greater range of values

TABLE 1

Application efficiency summary ($E_a$) for irrigations applied by various techniques under two tillage conditions (from Lyle and Bordovsky, 1983)

| | Basin tillage[1] | | | Conventional tillage | | |
|---|---|---|---|---|---|---|
| | LEPA | Sprinkler | Furrow | LEPA | Sprinkler | Furrow |
| 1980 | | | | | | |
| Average $E_a$ | 99 | 77 | 91 | 91 | 76 | 89 |
| Range | 96–100 | 7– 97 | 82–99 | 80–100 | 7– 97 | 71–99 |
| 1981 | | | | | | |
| Average $E_a$ | 99 | 90 | 82 | 84 | 86 | 83 |
| Range | 96–100 | 79–100 | 58–98 | 69– 99 | 71–100 | 66–99 |
| Two-year average $E_a$ | 99 | 84 | 87 | 88 | 81 | 86 |

[1]Involves formation of small dikes in the furrows, thus resulting in small basins about 3–5 m long. Where furrow irrigation is used, the dikes are washed out as water advances down the furrows. In some cases, alternate furrows are diked and only the non-diked furrows are irrigated, thus providing for capture of rainwater in the diked furrows.

than the LEPA system. Smaller ranges for the LEPA system indicate that this system minimized the effects of soil and climatic variables (Lyle and Bordovsky, 1983).

*Eliminating tailwater runoff*

Tailwater runoff is eliminated by use of the LEPA irrigation system when used in conjunction with basin tillage (previous section). Another system that eliminates or minimizes tailwater runoff is the LID (limited irrigation – dryland) system developed by Stewart et al. (1981). As with the LEPA system, the LID system employs ridge tillage (furrows) in conjunction with basin tillage (diked furrows). The objective of the LID system is to prevent irrigation tailwater and storm runoff water from leaving a field, thus improving the efficiency of both irrigation water and rainfall for crop production in a conjunctive use system.

The system evaluated by Stewart et al. (1981) was designed to use a limited water supply to irrigate grain sorghum on an area larger than could be fully irrigated and thereby reduce the area of dryland sorghum for the producer who grows both irrigated and dryland sorghum. A 600 m long field was divided into three water management sections, with the upper half fully irrigated, the next quarter as a tailwater runoff section, and the lower quarter as a dryland section. The dryland section captured runoff resulting from irrigation and rainfall. Furrow dikes aided in controlling runoff. Seeding rates and fertilizer applications were adjusted for the different sections. Results for the

TABLE 2

Average rainfall, irrigation, runoff, soil water change, sorghum grain yield, evapotranspiration (ET), and water use efficiency (WUE) for the LID system, Bushland, Texas, 1979–1981 (from Stewart et al., 1983)

| Treatment | Rainfall[1] (mm) | Irrigation (mm) | Runoff (mm) | Soil water change[2] (mm) | Yield (Mg $ha^{-1}$) | ET (mm) | WUE (kg grain $m^{-3}$ water) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | seasonal ET | applied irrigation |
| Dryland | 250 | 0 | 30 | −74 | 2.53 | 295 | 0.84 | - |
| Fully irrigated | 250 | 516 | 177 | −30 | 7.24 | 619 | 1.17 | 0.92 |
| LID - 250 mm | 250 | 233 | 9 | −45 | 5.69 | 520 | 1.08 | 1.36 |
| LID - 185 mm | 250 | 174 | 5 | −46 | 5.13 | 466 | 1.09 | 1.50 |
| LID - 125 mm | 250 | 119 | 11 | −52 | 4.47 | 411 | 1.08 | 1.70 |
| LSD (0.05) | - | - | - | - | 0.71 | 47 | 0.20 | 0.64 |

[1]Rainfall between seeding and harvest dates.
[2]Change in soil water to a 1.8 m depth between seeding and harvest dates.

study after three years were summarized by Stewart et al. (1983) and are given in Table 2. Although grain yields with the LID systems were lower than with full irrigation, the LID systems permitted very little runoff, while average runoff was 177 mm with full irrigation. Full irrigation also resulted in lower irrigation water use efficiency than the LID system. The results given in Table 2 are averages for all areas (fully irrigated, runoff, and dryland) of the LID systems.

### *Deficit irrigation*

Deficit irrigation is the practice of using limited water supplies over an area larger than that which can be adequately irrigated for high yields and not fully replenishing with irrigation the water removed from a soil by evapotranspiration (ET). For conditions of favorable soil water storage and/or growing season precipitation, deficit irrigation may have little or no effect on yields of drought-tolerant crops. When deficit irrigation is used where soil water storage and precipitation are limited, crops usually experience water stress at some time during the growing season, thus reducing yields. Yield reductions, however, can be minimized by managing the water stress, that is, by allowing stress to occur at the less critical growth stages and providing water at the more critical stages. Grain sorghum (Musick and Dusek, 1971; Eck and Musick, 1979), winter wheat (Schneider et al., 1969), and sunflower (*Helianthus annuus* L.) (Unger,, 1982) respond well to irrigations at critical growth stages.

Cotton also is widely grown under deficit irrigation (Musick and Walker, 1987).

As in full irrigation practices, ridge tillage (furrowing) is important for managing water under deficit irrigation practices. The furrows aid the control of the flow of water and improve uniformity of distribution. However, deficit irrigation reduces uniformity of application with furrow irrigation while increasing application efficiency. Deficit irrigation should have very little effect on uniformity of application by sprinklers or the LEPA system, but plant water deficits can reduce uniformity of yields.

Deficit irrigation can be achieved by irrigating less frequently or by applying less water per irrigation. For maximum effectiveness, deficit irrigation by less frequent water application should strive to provide water in advance of the crop's most critical growth stage. Reduced application depths in deficit irrigation systems can be achieved by decreasing or eliminating tailwater runoff, and by reducing infiltration by furrow compaction, using surge-flow irrigation, and using wide-spaced furrow or alternate furrow irrigation. The first three methods have been discussed previously with regard to conserving water. In general, their effects with respect to deficit irrigation would be similar to those for water conservation, and they will not be discussed further. In this section, the emphasis is on irrigating wide-spaced or alternate furrows to achieve limited water applications to crops.

Irrigation of widely spaced and alternate furrows has been evaluated for various crops in the Texas High Plains, the Oklahoma Panhandle, and at Texas locations near El Paso (not on the High Plains). In the Oklahoma studies, irrigating widely spaced or alternate furrows resulted in a major reduction in water application with little or no yield reduction as compared with irrigating conventionally spaced furrows (Stone et al., 1979, 1982). The crops were grain sorghum, cotton, and soybeans (*Glycine max* L.).

Musick and Dusek (1974) compared alternate furrow with every furrow irrigation of potatoes (*Solanum* sp.) on Pullman silty clay loam at Hereford and grain sorghum and sugar beets (*Beta vulgaris* L.) on Pullman clay loam at Bushland, both on the Texas High Plains. Reductions in water infiltration with alternate-furrow irrigation ranged from 13% to 33%. Alternate-furrow irrigation had little effect on water infiltration and potato yields on the silty clay loam soil, but significantly reduced infiltration and yields of sugar beet and sorghum on the clay loam soil. The decreased infiltration and yields occurred mainly on the lower one-quarter to one-half of the field plots, especially when irrigated furrow spacing was 2 m and very little tailwater runoff was allowed. Of different spacings tested, Musick and Walker (1987) indicated that a furrow spacing of 1.5 m was best on the Pullman clay loam soil. Wider spacings resulted in major lower-field yield reductions. The 1.5-m spacing is being adopted for row crop production with two 0.75-m-spaced crop rows per ridge. The wide ridge system permits wheel traffic on the ridges, if desired, thus maintaining conditions favorable for water infiltration in the furrows.

Longenecker et al. (1969) compared every-furrow (1.02-m spacing) irrigation with variable row spacing (VRS) irrigation for cotton near El Paso, Texas. The VRS system consisted of an alternate wide (1.37-m) and narrow (0.66-m) row arrangement with irrigation only in the furrows between the 0.66 m spaced rows. There were no furrows between the wide-spaced rows. For two methods of cotton management (thinning vs. not thinning), two irrigation frequencies (seven or five per season), and three cultivars, average total water applied was 840 mm with regular row spacing and 560 mm with VRS in a three-year test on leveled land. Lint yields averaged 1.09 and 1.10 Mg ha$^{-1}$ with regular and VRS irrigation, respectively, for studies conducted at three locations involving leveled and sloping land conditions.

On the basis of results obtained on Pullman clay loam at Bushland, Texas, and on Richfield clay loam (fine, montmorillonitic, mesic Aridic Argiustoll) at Goodwell, Oklahoma, where average seasonal rainfall is similar at both locations (200–250 mm), Musick and Walker (1987) concluded that irrigation of wide spaced furrows is more successful on moderately-permeable, medium-textured soils (e.g. Richfield clay loam) which are subject to deep percolation losses of water when irrigated with conventional furrow spacings than on slowly-permeable, fine-textured soils (e.g. Pullman clay loam). For the Texas High Plains, success of wide spaced furrow irrigation is attributed to rainfall, which normally provides about 30–40% of the water required by crops. Irrigations that do not fill the soil profile, as with wide spaced furrow irrigation, result in some storage capacity being available for water from rainfall that may occur shortly after an irrigation.

## CROP ESTABLISHMENT, GROWTH, AND YIELD

A ridge and furrow system is the most widely used water control practice for surface irrigation of sloping soils. With this system, capillary movement of water from the furrows to higher elevations on the ridges results in optimum seed zone conditions for planting on the ridges, which were previously formed from loose surface soil. The ridge tillage system has some other advantages and some disadvantages with respect to crop establishment on irrigated land. Any effects on crop growth and yields would generally be related to non-uniform crop establishment. Hence, growth and yields will not be discussed.

### *Advantages*

Advantages of ridge tillage for crop establishment include the following: traffic control; provision for precision planting, especially of small-seeded crops; opportunity for planting in moist soil without planting too deeply; control of gravity-flow irrigation for germination and seedling emergence, if necessary; opportunity for successful crop establishment on saline soils; potential for reducing erosion. These advantages, in general, pertain to row crops and not to crops that are drill or broadcast planted.

After ridge tillage is performed, subsequent traffic can usually be controlled and confined either to the furrow or to flat ridges in case of wide ridge systems. By controlling traffic, seed zones can be maintained in a favorable, noncompacted condition, thus favoring satisfactory crop establishment. Crop establishment on some soils is difficult when seeding occurs where the soil has been compacted by traffic.

Precision planting is possible when ridge tillage has been performed in advance of the planting operation. When ridges are sufficiently high, the ridge tops can be shaped (flattened) or reduced in height during the planting operation, thus providing for uniform depth of planting, which may be highly critical for small-seeded crops. Also, removal of dry soil improves seed zone soil water contents for moderate to shallow seeding depths.

Under the semiarid conditions of the Southern Great Plains, precipitation is generally highly variable and may not occur at the opportune time for crop establishment. However, if ridge tillage has been performed well in advance of planting, the soil may contain sufficient water for crop establishment. It may be necessary to remove the ridge tops in order to plant in moist soil, but such an operation often retains ridges of sufficient height so that growing season furrow irrigations can be accomplished without difficulty. In some cases, ridges and furrows are reshaped during cultivation. Crop establishment under such conditions improves the use of precipitation for crop production and avoids the use of a pre-plant irrigation, which often results in excessive infiltration and is highly inefficient in terms of soil water storage for later use by the crop (Musick and Walker, 1987).

When soil water contents at planting time are too low for satisfactory crop establishment, ridge planting followed by an irrigation can be used to achieve timely and satisfactory crop establishment. Furrow irrigation under dry soil conditions results in excellent wetting of the ridge without the excessive crusting and reduced emergence that are often associated with rainfall or sprinkler irrigation. When rainfall that causes a crust occurs immediately after planting and the crust limits emergence, soil loosening with a rotary hoe often results in satisfactory crop establishment. In extreme cases, crop replanting may be necessary.

On saline soils, surface layer salts move to the ridge tops during irrigation and first stage evaporation. When ridge tillage is used, seeding on the side of the ridge reduces seed zone salinity problems and hence results in improved conditions for germination.

Well designed ridge–furrow systems have furrow grades that improve surface drainage of storm runoff water by reducing water concentrations and velocities of overland flows, thus reducing the potential for soil erosion. On poorly designed systems, excessive furrow grades and irrigation flow rates could cause erosion, thus resulting in poor establishment of a furrow-planted crop such as wheat, and in limited infiltration of irrigation water.

### *Disadvantages*

Disadvantages of ridge tillage with respect to crop establishment include increased drying of ridged soil, furrow compaction, which increases planting problems of a crop such as wheat that is drill-planted on ridges and in furrows, and emergence problems of furrow-planted crops that must be irrigated for germination and emergence.

Ridge tillage exposes more soil to the atmosphere than flat tillage. Hence, increased drying of the ridge can lower soil water contents for germination and emergence, and result in poor crop establishment or the need for an irrigation for satisfactory crop establishment. Irrigation for crop establishment increases crop production costs in areas where precipitation can be relied upon for seed zone wetting and crop establishment.

Field traffic after the ridging operation usually results in compaction of some furrows. Such compaction does not affect row-crop establishment on ridges, but may adversely affect establishment of a drill-planted crop such as winter wheat that is planted on ridges and in furrows. The problem arises when the drill openers in furrows fail to penetrate the soil to achieve adequate depth of planting or when there is inadequate loose soil to satisfactorily cover the seed. As a result, plant populations in furrows may be low unless timely rainfall occurs or an irrigation is applied to aid in seedling establishment.

When a crop such as wheat is drill-planted on ridges and in furrows and is furrow-irrigated for germination and seedling establishment, loose soil transported and/or settled by flowing water may cover the seed in furrows too deeply for satisfactory emergence.

## SUMMARY

About 66% of all irrigated land in Texas is on the High Plains, and about 60% of that land is furrow irrigated (ridge tilled). Furrow irrigation is used on about 90% of the slowly permeable soils (mostly Pullman and Sherm series) that are irrigated on the Texas High Plains.

Pullman and Sherm soils are generally well adapted to furrow irrigation because of their relatively flat topography (slope usually less than 1%) and their low permeability. These factors permit irrigation of furrows 800–1600 m long and relatively long irrigation sets (up to 24 hours) with very low water losses due to deep percolation. The low permeability, however, results in poor wetting of the lower end of fields unless tailwater runoff is permitted for several hours (up to six or eight hours). Such runoff is wasteful unless the water is captured for other purposes or recycled through the irrigation system. Practices that minimize or eliminate tailwater runoff losses include deep tillage (especially on the lower end of the field), surge irrigation, LEPA irrigation, LID systems, and deficit irrigation. In general, the goal for these practices is to improve application efficiency and/or to enhance utilization of precipitation in the crop production system. A disadvantage is decreased distribution uniformity.

On more permeable soils, deep percolation of furrow-applied irrigation water may be excessive. Practices for decreasing such losses include surge irrigation, LEPA irrigation, furrow compaction, deficit irrigation (irrigating wide spaced or alternate furrows), and eliminating the preplanting irrigation.

As compared with crop production under flat-tilled conditions, there are some advantages and disadvantages with ridge tillage for crop establishment, which may subsequently affect crop growth and yield. The advantages include: improved traffic control, provision for precision planting, opportunity for planting in moist soil without planting too deeply, control of gravity flow irrigation for germination and emergence, if necessary, opportunity for successful crop establishment on saline soils, and potential for decreasing erosion. Disadvantages include increased drying of ridged soil, furrow compaction, which may increase planting problems of crops planted on ridges and in furrows (e.g. wheat), and emergence problems of furrow-planted crops that are irrigated for germination and emergence. In general, the disadvantages can be overcome by careful management. Consequently, furrow irrigation of ridge-tilled land is an effective and widely accepted method of crop production on much of the irrigated land in the Southern Great Plains.

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